SELECTED ASPECTS OF THE BREEDING BIOLOGY OF TWO LAKE ERIE HERRING GULL COLONIES

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ABSTRACT

Aspects of the breeding biology of two Lake Erie Herring Gull colonies were studied in 1975 and 1976. In 1976 the incubation attention given 2-egg and 3-egg clutches initiated early and late in the season was measured. Brood size at one colony was artificially increased or decreased by addition of chicks shortly after hatching.

Hatching success was not consistently related to clutch size but early nesters were more successful than late nesters. Differences in hatching success between 2-egg and 3-egg clutches were a function of the time of clutch initiation with the clutch size having the greater proportion of its nests initiated early in the season being more successful.

The incubation attentiveness of parents of 2-egg and 3-egg, and early and late clutches was similar. Most nests were incubated greater than 95% of the time although their hatching success was similar to those incubated less than 75% of the time.

Fledging success, chick growth and weight at fledging were similar among broods of one, two and three chicks and artificially increased broods of four and five chicks. Fledging success was highest for one chick broods reduced from two and three chick broods.

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1. INTRODUCTION:

Long-term changes in numbers have been reported for several species of colonial seabirds in North America. Herring Gull (*Larus argentatus*) numbers in New England colonies have doubled every twelve to fifteen years since 1900 (Kadlec and Drury 1968), although a more recent interpretation suggested that the population as a whole has stabilized over the last two decades (Drury and Kadlec 1974). The numbers of Ring-billed Gulls (*L. delawarensis*) on the Laurentian Great Lakes increased markedly since 1960 (Ludwig 1974), whereas numbers of Common Terns (*Sterna Hirundo*) declined in Massachusetts (Nisbet 1973) and colony desertions have been reported in the Great Lakes (Morris and Hunter 1976a).

Aspects of the breeding biology of the Herring Gull are best documented from studies on the Atlantic coasts of north-eastern United States, eastern Canada and western Europe (Darling 1938, Paynter 1949, Harris 1964, Kadlec and Drury 1968, Brown 1967, Parsons 1975, Haycock and Threlfall 1975).

In Lakes Michigan and Ontario low reproductive success of Herring Gulls has been linked to high organochlorine levels (mainly DDE and PCB's) in the eggs and tissues of adult birds (Ludwig and Tomoff 1966, Keith 1966, Gilbertson and Hale 1974a, 1974b). However, detailed, long-term, demographic data on the breeding biology of the Herring Gull on the Great Lakes is lacking.

It was the purpose of this study:

(1) to assess the reproductive success of two Lake Erie Herring Gull colonies

(2) to assess the influence of clutch size and time of clutch initiation on hatching success

(3) to assess the effect of artificially increasing brood size on chick survival and growth.

(4) to assess the influence of a number of other parameters on reproductive success; including egg volume, order of laying and toxic chemical residue levels in eggs.

2. LITERATURE SURVEY

Early work on Herring Gull breeding biology was generally descriptive in nature, focusing principally on breeding behavior (eg: Bent 1921, Darling 1938, Tinbergen 1953, 1959). Later studies focused more on the collection of demographic parameters relating to population dynamics (eg: Harris 1964, Brown 1967, Kadlec and Drury 1968, Haycock and Threlfall 1975).

(a) Description and Range:

The Herring Gull (Figure 1) is a colonial, ground-nesting seabird with an elaborate behavioral repetoire consisting of a number of postures and vocalizations. Herring Gulls are apparently monogamous and may retain the same mate from season to season. (Tinbergen 1953).

The Herring Gull has a breeding range in North America from central and north-central Canada and western Greenland south to western interior Canada, northern Minnesota, central Michigan, northern New York and casually to north coastal Virginia; also in Iceland, Europe and northern Siberia (Godfrey 1966).

(b) Clutch Size and Incubation Period:

Birds return to the breeding colony in March and the first egg is laid in mid-April over most of the breeding range. The normal clutch size of the Herring Gull is three but two-egg clutches are frequent and one egg clutches and clutches larger than three are rare. Mean clutch sizes for a number of colonies are in Table 1.

Figurel: The Herring Gull.

TABLE 1

Observed mean clutch sizes of a number of Herring Gull colonies.[1]

Colony	No. of nests	Mean clutch size	Study
Kent I. New Brunswick	1011	2.38	Paynter (1949)
Graesholm I. Wales	-	2.91	Paludan (1951)
Skomer I. Wales	220	2.8	Harris (1964)
Walney I. England	139	2.56	Brown (1967)
Muggs I. Toronto, Ont.	36	2.92±.08[2]	Haymes (unpublished 1973)
Gull I. Newfoundland	113	2.73	Haycock and Threlfall(1975)

[1] Observed mean clutch size approaches 3.00 as the intensity of the study increases (Harris 1964, Keith 1966, Kadlec and Drury 1968).

[2] 1 standard error

The clutch size of birds has been accounted for by four different hypotheses (Lack 1954):

i) A bird lays as many eggs as it is physiologically capable of producing.

ii) Clutch size is limited by the number of eggs that the sitting bird can cover.

iii) Clutch size has been adjusted by natural selection to balance the mortality of the species.

iv) Clutch size has evolved through natural selection to correspond with the largest number of young for which the parents can, on average, find enough food.

Herring Gulls are indeterminate layers (Paludan 1951, Harris 1964) that is, if eggs are removed immediately following laying the bird will continue to lay eggs up to a limit somewhat larger than the normal clutch size of this species. Thus, clutch size does not appear to be limited by the physiological capacity of the bird. In the Partridge, *Perdix perdix*; mean clutch 15 eggs) and Wood Duck (*Aix sponsa*; mean 11-14 eggs) clutches of up to twenty eggs hatched a similar percentage of eggs as clutches near and below the mean (Lack 1947, Leopold 1951). Thus, although there must be a limit to the number of eggs that a bird can effectively incubate, this limit is not necessarily the normal clutch size. For clutch size to be adjusted to the mortality of the species a mechanism to measure mortality or population density would be needed (cf Wynne-Edwards 1962). It would be expected that if clutch size were controlled by mortality, clutch size would be lower during times of high population density than at low densities. This is not the case in Herring Gulls as mean clutch sizes are similar in small, 50 pair, colonies on the Great Lakes and large, >100 pair, colonies on the Atlantic coast. Also, natural selection operates on the survival rate of the offspring of each individual or genotype and would be expected to select for that type which produced the largest number of breeding offspring even if there was over-population (cf Lack 1954).

Lack (1954,1966) supported the final hypothesis with numerous examples. Dealing generally with passerine birds, he demonstrated that with increased brood size feeding visits by adults increased but not in the same proportion as the brood size and that the number of chicks fledged per nest decreased as brood size increased.

Lack's hypothesis has been tested by Vermeer (1963) with Glucous-winged Gulls, L. glaucescens, and by Nelson (1964) with Gannets (Sula bassana). At Bass Rock, Scotland Nelson found that Gannets (modal clutch of 1) successfully raised broods of twins and on Mandarte Island B.C. Vermeer demonstrated that Glaucous-winged gulls (modal clutch of 3) raised increasingly more chicks to fledging with broods of four, five and six chicks. Lack (1966) argued that in both these studies birds were able to raise super-normal broods due to an "unusually favourable ...food situation ... at the colonies concerned", and that the commonly observed clutch size evolved under food-limited conditions when fewer numbers of chicks could normally be raised to fledging.

The incubation period of Herring Gulls varies between 28-33 days (Tinbergen 1953) and decreases as the season progresses (Parsons 1972). This decrease in incubation time may be due to one or more of several factors. These include more favourable weather conditions (MacRoberts and MacRoberts 1972), decreased egg volume (Parsons 1972) and changes in parental behavior such that the eggs are left for shorter periods of time later in the breeding season (MacRoberts and MacRoberts 1972).

c. The Chicks and Fledging Period

Herring Gull chicks are feathered upon hatching and are capable of locomotion shortly after hatching. The chicks are fed partially digested food regurgitated by the parent.

Reports of actual fledging age vary in the literature; Paynter (1949) recorded a mean of 43 days, Keith (1966) 40-45, Kadlec *et al* (1969) mean of 51 days and Haycock and Threlfall mean of 45 days.

d. Factors Influencing Reproductive Success:

i) Extrinsic Factors

Herring Gulls are opportunistic feeders utilizing a number of food sources. In recent years garbage dumps have become principal foraging areas. Food availability, however, has been suggested to be a factor affecting reproductive success in Herring Gulls. Hunt (1972) found that post-hatch mortality increased directly with distance to feeding grounds (garbage dumps) in Maine. Colonies on outer islands (farthest from feeding grounds) realized a fledging success in 1969 and 1970 lower (28% and 20% respectively) than islands closer to the feeding grounds (57% and 43%). Similar results were reported for Dominican Gulls, L.dominicanus, in New Zealand (Fordham 1970).

Brown (1967) suggested that predation by neighbouring Herring Gulls was the major cause of egg loss in a Herring Gull colony on Walney Island, England. Predation in a Gull colony is dependent mainly upon its location and the number of predators having access to the colony. Egg predators include Great Black-backed Gulls, L. marinus (Erwin 1971); Crows, Corvus brachyrhynchos (Keith 1966); Brown Rats, Rattus norvegicus (Brown 1967), and neighbouring Herring Gulls (Paynter 1949, Brown 1967).

Most chick losses to predators occur in the first week post-hatch when they are in the down stage and at a size when they can be eaten whole. Predators of chicks, reported in Britain, include; other Herring Gulls (Brown 1967); Great Black-backed Gulls (Harris 1964); Carion Crow, C. corone and Buzzard, Buteo buteo (Harris 1964); Grey Heron, Ardea cinerea (Darling 1938), and in New England, Red Fox, Vulpes fulva and Raccoon, Procyon lotor (Kadlec 1971).

Human interference has also been found to effect the reproductive success of colonial seabird species. Robert and Ralph (1975) found that pre-hatch mortality of Western Gulls, L. occidentalis, on the Farallow Islands, California increased directly with the frequency of regular 30 minute human disturbances although post-hatch mortality decreased due to an apparent acclimation to the presence of the investigator. In contrast, the study of Gillett et al (1975) reported a higher post-hatch mortality of Glaucous-winged Gull chicks on Colville Island, Washington in areas of intensive investigation compared to areas of low investigative effort. There was no difference in pre-hatch mortality. Hunt (1972) found in Maine that Herring Gulls nesting on islands with high human interference (measured by observation and the number of old campfires) realized a lower hatching success than islands with low human interference.

Low reproductive success of Herring Gull colonies, as well as that of many other bird species high in the food chain, has been correlated to high levels of organochlorine contaminants, most notably PCB's and DDT derivatives, in the eggs and tissues of adult birds. Such pollutants may reduce productivity in birds by egg shell thinning (Hickey and Anderson 1968, Cooke 1973), embryonic mortality (Keith 1966) or abnormal parental behavior (McEwen and Brown 1966).

Gilbertson (1974) suggested that organochlorine residues of Herring Gull eggs in eastern Lake Ontario resulted in low hatchability due to a high incidence of embryonic mortality and egg breakage and flaking. The number of young fledged per pair of adults in Gilbertson's study (0.06 to 0.21) was one tenth that of colonies on the Atlantic coast where toxicant levels are lower (Hickey and Anderson 1968). Keith (1966) found a hatching success of 41% (n = 115 nests) due to 35% egg mortality linked to toxicant load in Lake Michigan Herring Gulls.

ii) Intrinsic Factors

Several studies correlate hatching success and clutch size in the Herring Gull, with three-egg clutches more successful than smaller clutches (Paynter 1949, Harris 1964, Brown 1967, Parsons 1975, Haycock and Threlfall 1975) Kadlec and Drury (1968), however, found hatching success to be independent of clutch size in New England.

Beer (1961) with Black-headed Gulls, L. ridibundus, and Brown (1967) with Herring Gulls suggested that hatching success is reduced in smaller clutches because the incubating birds tend to perform more rising and settling movements on the nest and thus are not as effective incubators. Parsons (1975) showed that three-egg clutch parents relaying smaller clutches following the removal of their original clutches realized a higher hatching success than that of small first clutches but lower than three-egg second clutches. Thus it would appear that low hatching success of small clutches is not solely due to the number of eggs in the nest.

A similar relationship is reported for hatching success and time of clutch initiation with early nesters or those nesting during the peak of nesting more successful than those nesting later in the season (Brown 1967; Kadlec and Drury 1968; Erwin 1971; Parsons 1975), although Harris (1969) found the opposite trend in a colony in Wales. Parsons (1975) demonstrated that eggs laid at the time when most laying occured were most likely to hatch regardless of the time of the season . Thus, late breeding would not necessarily be disadvantageous providing the delay applied to the group as a whole.

Age of the breeding birds has been found to influence a number of biological parameters in colonial seabird species. Age has been related directly to an increase in egg volume in the Kittiwake, Rissa tridactyla (Coulson 1962); Artic Tern, Sterna paradisaea (Coulson and Horobin 1976), and the Herring Gull (Davis 1975); an increase in clutch size in the Kittiwake

(Coulson and White 1961) and the Herring Gull (Chabrazyk and Coulson 1976) and an increase in the number of chicks fledged per pair in the Herring Gull (Chabrazyk and Coulson 1976).

Colony size may also influence the reproductive success of Herring Gulls. Darling (1938) using data for a number of Herring Gull colonies in the Priest Islands, Scotland, suggested that the number of young fledged per nesting pair was dependent upon nesting synchrony gained through high nest density and social stimulation. He suggested that if predator effort is constant throughout the season a higher percentage of chicks will be taken from the non-synchronous colony which has chicks in the down stage, when chicks are most vulnerable, for a longer period of time (Figure 2). Similarly Nelson (1966) found that high density led to greater synchrony of nesting in Gannets (Sula bassana), however Orians (1961) and Coulson and White (1956, 1960) suggested that other parameters including age structure and lack of environmental uniformity may also explain some of the differences in Darling's colonies.

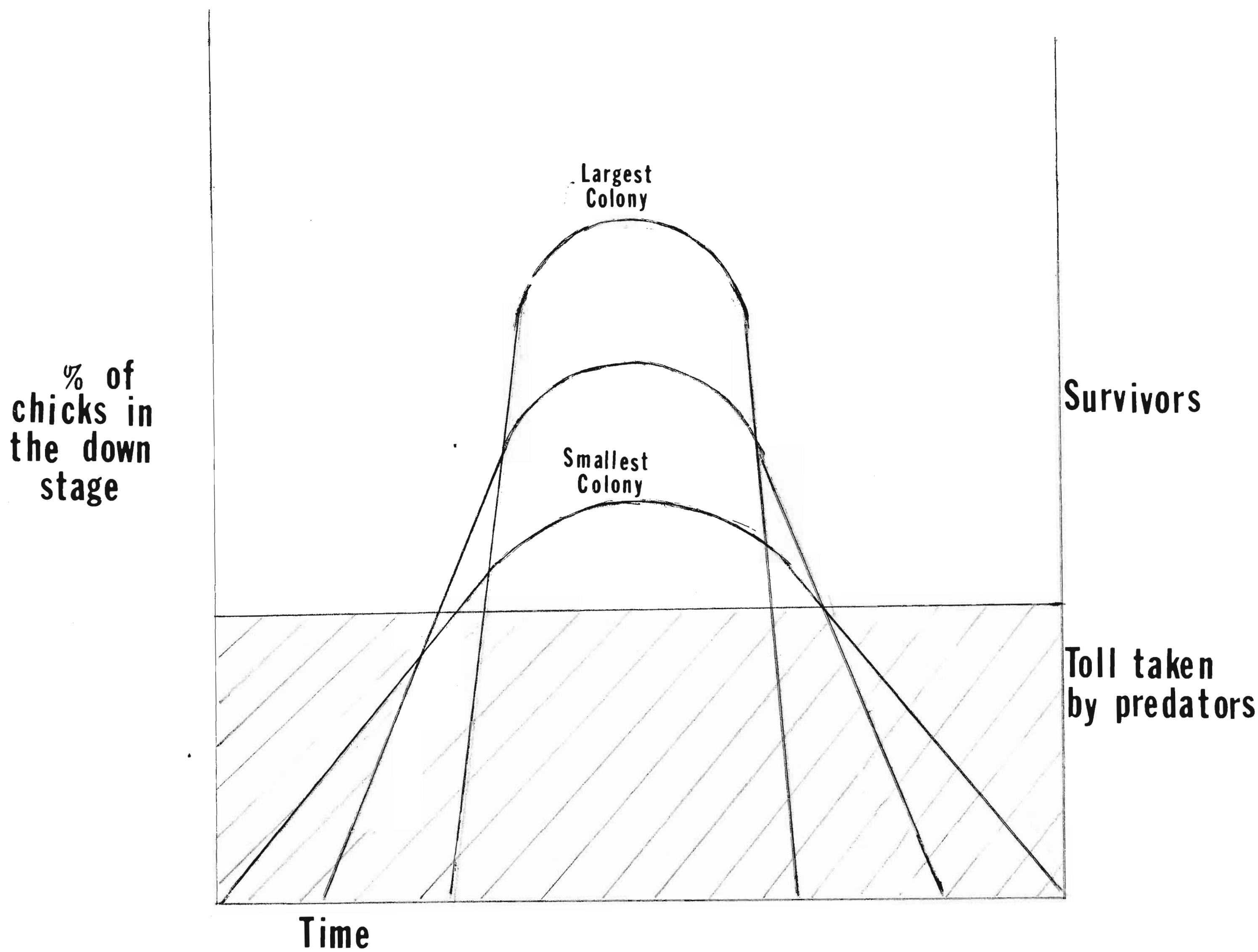

Figure 2: The Darling hypothesis: survival of chicks as influenced by colony size (after Darling 1938).

3. THE STUDY AREAS:

This study took place at two Herring Gull colonies in Port Colborne, Ontario at the Lake Erie terminus of the Welland Ship Canal. One, the Lighthouse colony was situated on an elevated pile of loose limestone rock, part of a man-made breakwater and lighthouse complex; the second, the Canada Furnace colony was situated on the property of Algoma Steel Corporation, Canada Furnace Division, approximately 1 km. from the Lighthouse colony.

A number of differences existed between the two colonies. The Lighthouse colony was 0.5 km from shore, whereas the Canada Furnace colony was on the mainland. The lighthouse-breakwater complex was accessable by boat and was frequented by fishermen, picnicers and bathers, although the actual nesting areas were rarely entered. The Canada Furnace colony was fenced off and accessible only to plant personnel but nests were often destroyed by routine plant operations.

Herring Gulls at the Lighthouse colony nested exclusively on loose limestone rock while a number of substrate types were utilized at the Canada Furnace colony. These included flat grassy areas and large stock piles of grannular slag (Figure 3).

Ring-billed Gulls (*Larus delawarensis*) and Common Terns (*Sterna Hirundo*) were also nesting at both colonies. At the Lighthouse colony nests were clumped (3.6×10^{-2} nests per m^2) apart from the other two species (Figure 4). At the Canada Furnace a

b

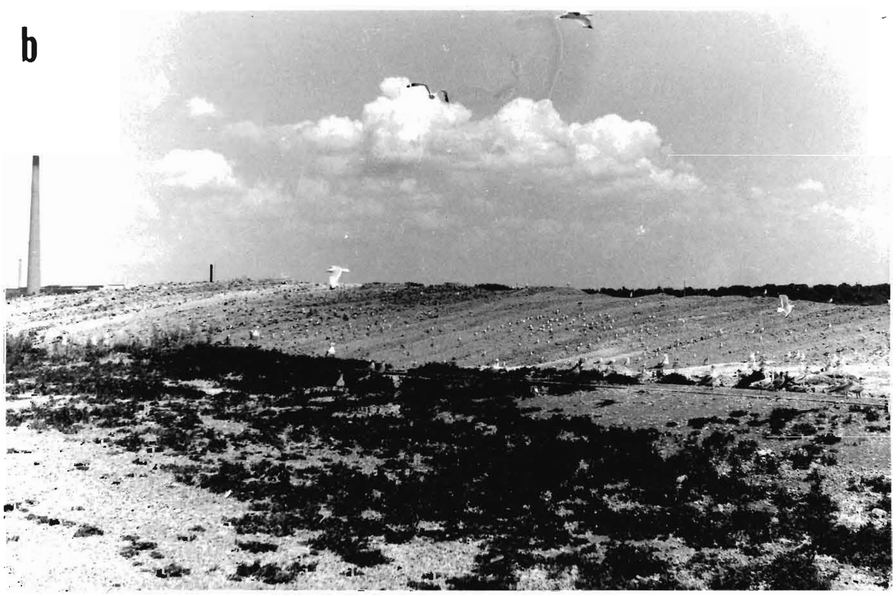

Figure 3: Typical terrain of the a) Lighthouse and b) Canada Furnace colonies.

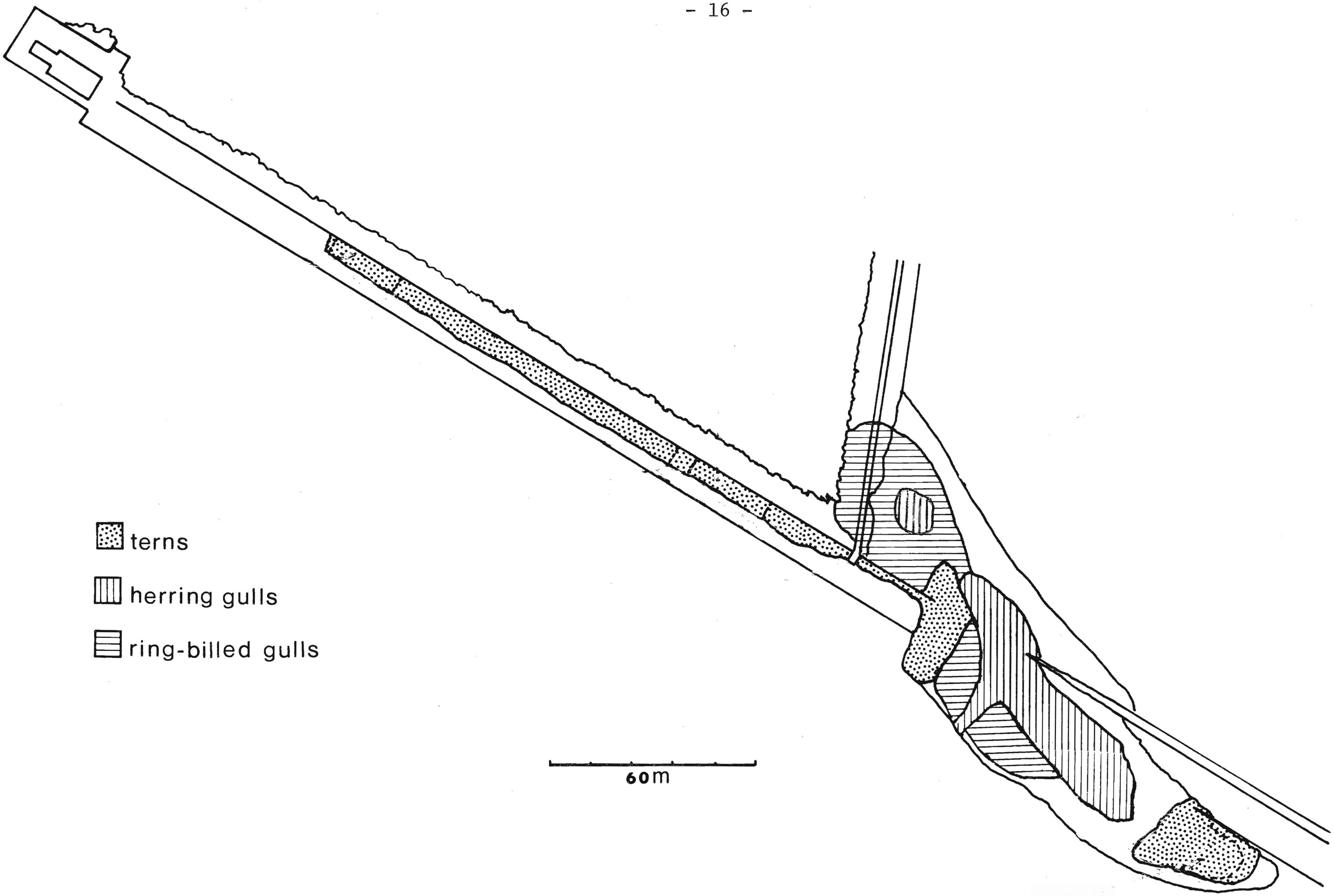

Figure 4: Species distribution at the Lighthouse colony.

colony, however nests were widely scattered (1×10^{-3} nests per m^2) with approximately half of the nests intermingled among Ring-billed Gull nests (Figure 5).

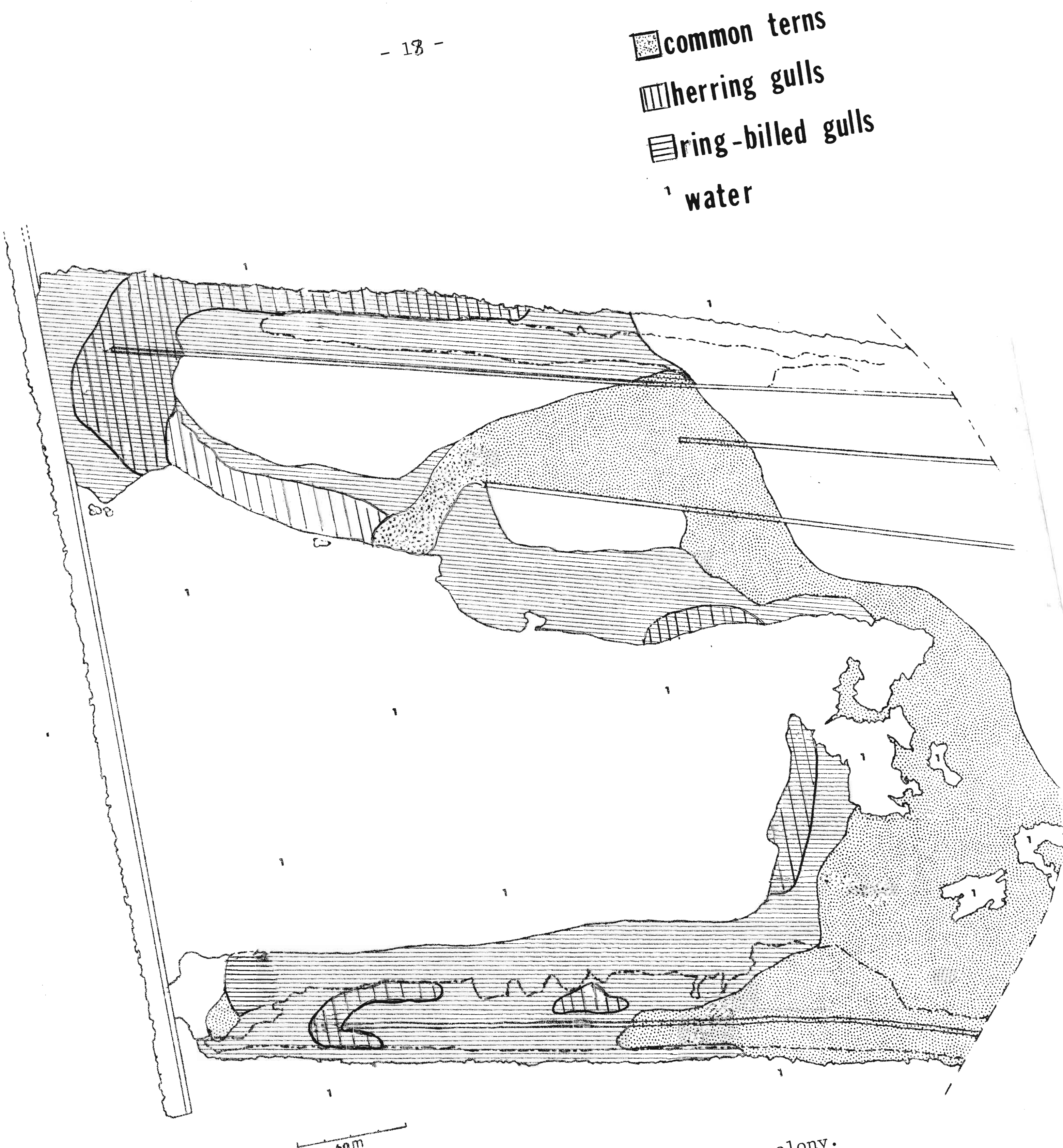

Figure 5: Species distribution at the Canada Furnace colony.

4. METHODS AND MATERIALS:

In 1975 and 1976 visits were from mid-April, prior to the laying of the first egg, until mid-July when the last chick had fledged or was near fledging. Visits were daily, weather permitting during the initial laying period (mid-April to early May) and during the peak hatching period (late May to early June); at other times visits were generally every second day.

Nests were marked with wooden tongue depressors and eggs were numbered with non-toxic felt markers in the order in which they were laid. The volume of each egg was determined, in 1976, by measuring the length and breadth with a vernier caliper and by the formula of Grossfield (1938; in Harris 1964); $V = kld^2$, where V is the volume, l is the length, d is the breadth and k is a constant evaluated for Herring Gull eggs as 0.476 (Harris 1964). Each egg was handled on every visit to determine its state of viability.

A sample of 28 nests, two and three-egg clutches started early and late in the season, was selected from the Lighthouse colony in 1976 for a study of incubation attentiveness. The nests were monitored using a twenty-channel Esterline-Angus event recorder (Model A620X) and nest recording devices. The devices were similar to those described in Morris and Hunter (1976 b) with the following adjustments. Each device consisted of a chromel wire ring attached to a micro-switch by a leaf spring (Figure 6). When the bird was incubating the micro-switch was closed. The system was powered by a 110 volt a.c. outlet from the lighthouse approximately 300 m from the recorder. The voltage was regulated at the recorder. Nests were monitored within the time period of day 13 to 27 of the incubation period.

A small sample of eggs were collected from the Lighthouse and Canada Furnace colonies in 1974 and 1975 for analysis of organochlorine residues. The analysis was completed by Dr.Lincoln Reynolds of the Ontario Research Foundation according to the procedures outlined in Reynolds (1969) and Reynolds and Cooper (1975).

Nests at the Lighthouse colony were fenced individually or in small groups (maximum 6 nests) just prior to or immediately following the hatching of the first egg. The fence was chicken wire mesh (2.5 cm. hexagonal hole size) with a minimum height of 60 cm. supported at regular intervals by steel or aluminum poles and anchored to the substrate by rock.

All chicks were banded upon hatching with U.S. Fish and Wildlife bird bands (size 6). Fledging time was taken as 30 days post-hatch since many birds, although incapable of strong flight were able to escape from the fenced areas at that age. At each visit thorough searches were made of the colony and the surrounding water in order to capture all birds which had escaped from the enclosures. Each chick was weighed on each occasion that it was found with a series of Ohaus field scales (Models 8011,

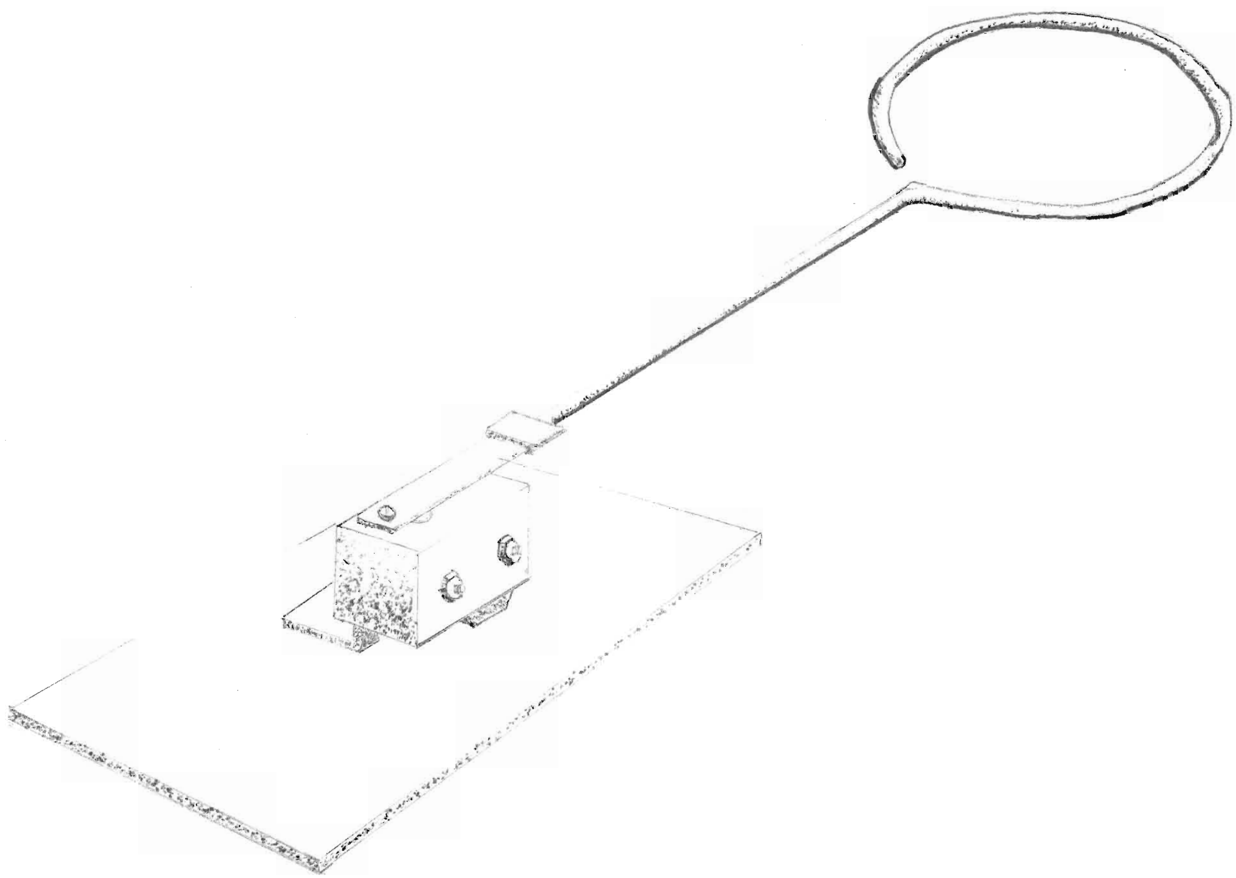

Figure 6: The incubation attention monitor.

8012, 8014, within 5% accuracy).

A number of nests at the Lighthouse colony were selected for a brood size manipulation experiment. Chicks were moved from one nest to another creating artificial broods of 1, 4 and 5 chicks (Table 2). All chicks were moved between May 26 and June 2 in 1975 and May 22 and June 7 in 1976. Chicks were moved within three days of hatching and placed in nests with chicks of similar age and weight. Chicks were moved from the Canada Furnace colony to supplement experimental chicks from the Lighthouse colony. Due to a lower mean clutch size and hatching success in 1976 (see Table 6), 2 and 3 chick broods reduced to 1-chick were pooled and 4 and 5-chick broods were produced from either 2 or 3 chick broods in 1976.

TABLE 2

Distribution of brood sizes and manipulations performed in 1975 and 1976.

1975	Original Brood Size	Manipulation	Final Brood Size	No. of Nests
	1	None	1	10
	2	None	2	9
	3	None	3	9
	2	-1	1	6
	3	-2	1	5
	2	+2	4	6
	3	+2	5	5
1976	1	None	1	13
	2	None	2	12
	3	None	3	4
	2[1]	-1	1	6
	3[1]	-2	1	2
	2[2]	+2	4	4
	3[2]	+1	4	1
	2[3]	+3	5	3
	3[3]	+2	5	2

1, 2, 3: pooled

5. RESULTS:

a. Nest Start Chronology:

Nest numbers and nest start chronology are in Table 3. At the Lighthouse colony, in each year, shortly following the laying of the first eggs, egg laying reached a peak after which the number of new clutches declined rapidly (Figure 7). However, at the Canada Furnace colony the initial peak was much reduced and laying continued at a high rate throughout the rest of the season.

b. Hatching Success:

The overall hatching success was 46.7% at Canada Furnace in 1975 and 61.8% and 54.2% at the Lighthouse colony in 1975 and 1976 respectively (Table 6). In 1975, when data were available from both colonies, the Lighthouse colony had a significantly higher hatching rate ($X_c^2 = 7.66$, $p < 0.01$; 2 x 2 contingency table, Yates correction for continuity; Siegel 1956). The difference between 1975 and 1976 at the Lighthouse was not significant ($X_c^2 = 1.73$, $p > 0.1$).

There was an apparent relationship between hatching success and egg volume at the Lighthouse colony in 1976 with mid sizes (85cc-94.99cc), comprising 70% of those laid, most successful (Figure 8). However, statistical tests showed that extremely small eggs (<80.0cc) were not significantly less successful than larger (>80.0cc) eggs ($X_c^2 = 1.055$, $p > 0.1$) nor did extremely large eggs (> 100.0 cc) hatch less successfully

TABLE 3

Clutch initiation chronology at the Port Colborne colonies.

	Canada Furnace 75	Lighthouse 75	Lighthouse 76
No. of nests	48	61	60
No. of eggs	128	184	169
Mean clutch size (±1 SE)	2.67±.12	3.02±.08	2.82±.09
First egg	April 22	April 20	April 18
End of peak[1] laying	April 30	April 28	April 27
Last clutch	June 1	May 29	June 7

[1]date when the rate of clutch initiation decreased (see Figure 7).

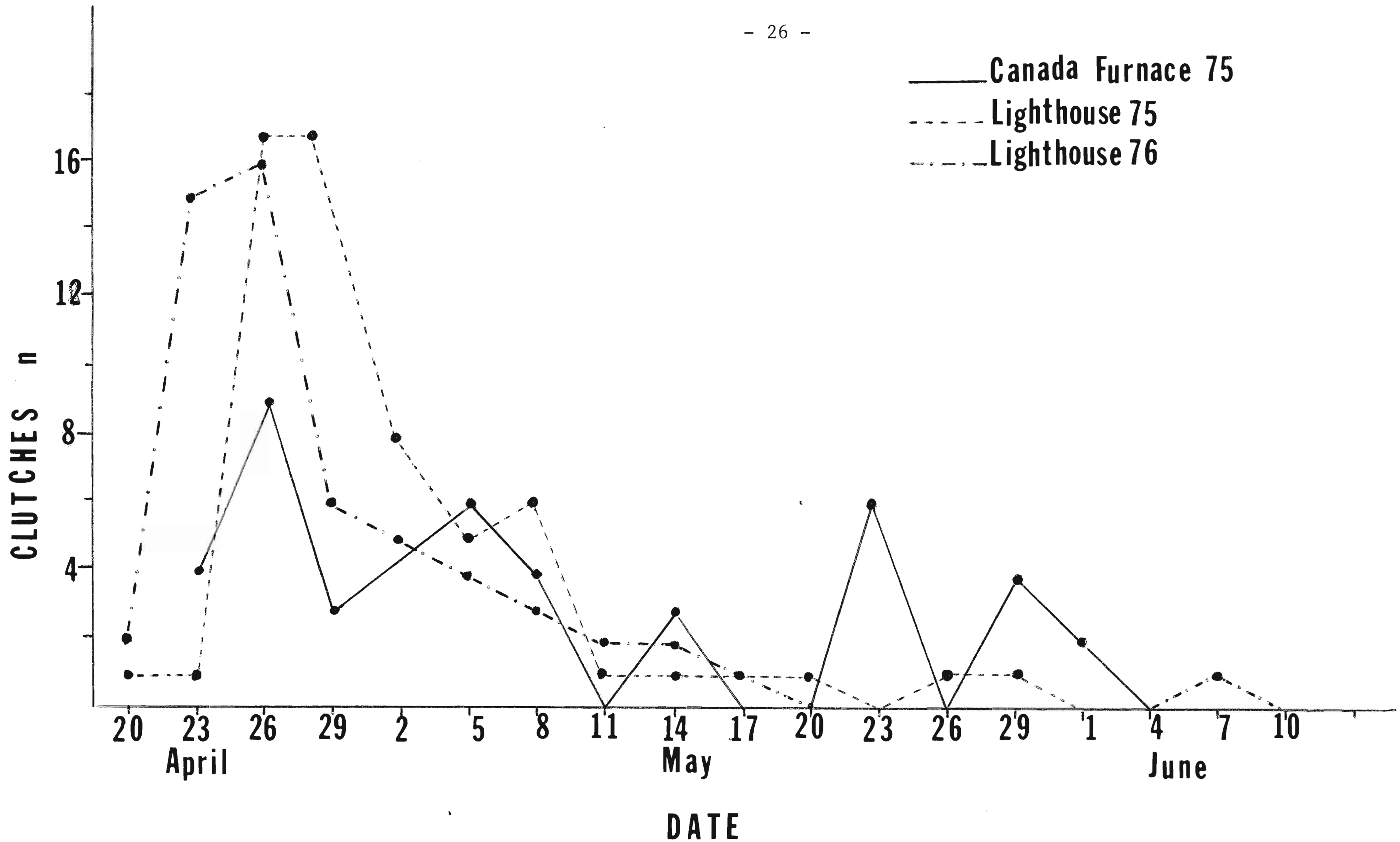

Figure 7: Distribution of clutch initiation, in three day intervals, at the Port Colborne colonies in 1975 and 1976.

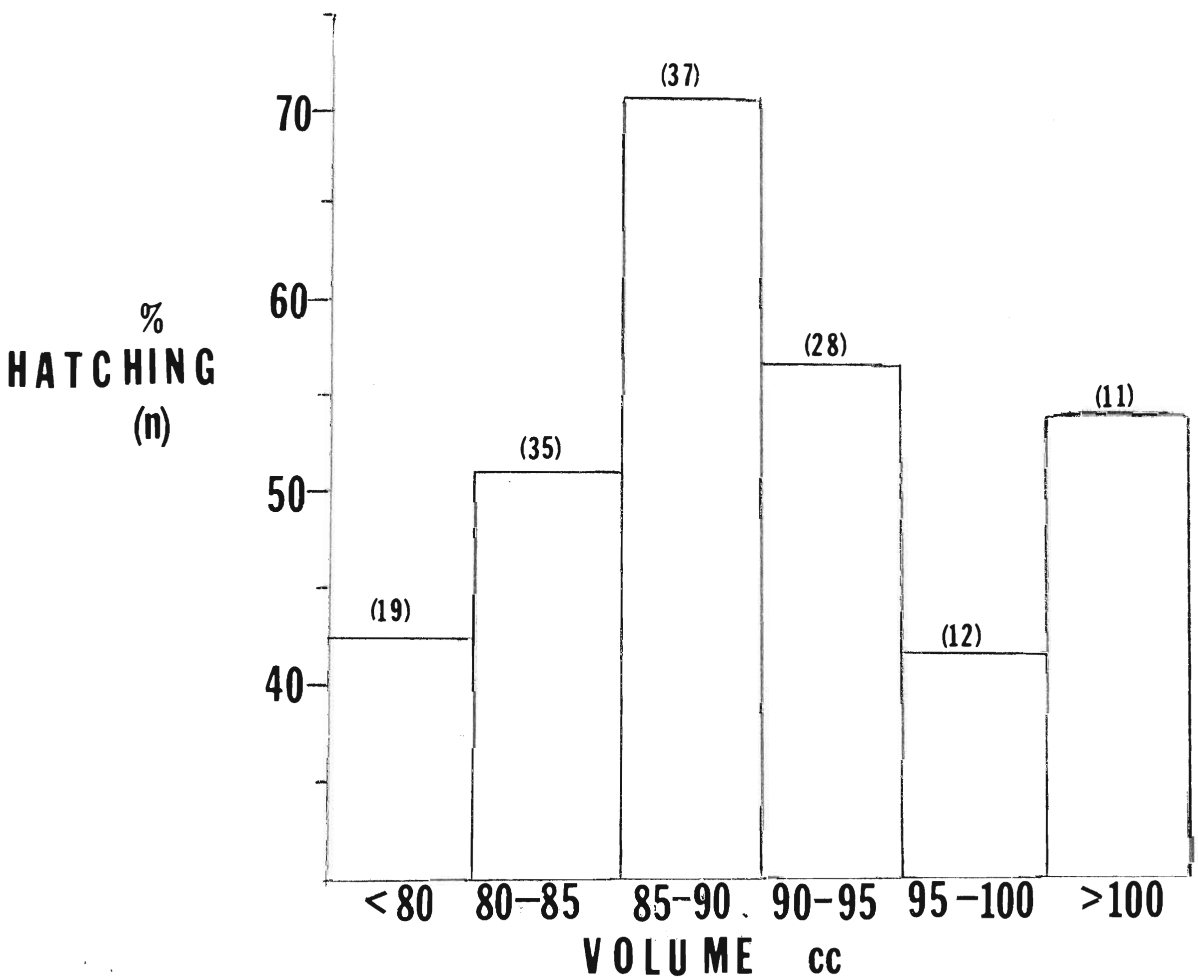

Figure 8: The relationship between egg volume and hatching at the Lighthouse colony in 1976.

than smaller (< 100.0cc) eggs ($X^2 = 0.153$). Finally, mid size (85-94.99cc) eggs were not significantly more successful than large (> 95.0cc) eggs ($X^2_c = 2.14$) but the difference between mid size eggs and small (< 85.0cc) eggs just failed to reach the required level of significance ($X^2_c = 3.54$, $0.1 > p > 0.5$).

Egg volume varied with the order of laying (Table 4). Second eggs of three-egg clutches contained the greatest volume followed by first and third eggs. The difference between second and third eggs was significant ($t = 2.06$, 68 df, $p < 0.05$) and marginally so between first and third eggs ($t = 1.97$; 68 df; $0.1 > p > 0.05$). The difference between first and second eggs was not significant ($t = 0.13$; 68 df).

In two of the three test cases third eggs of three-egg cluthces hatched more successfully than first or second eggs (Table 5); however, none of the differences among all possible combinations was significant (X^2_c tests). Thus, at the Port Colborne colonies hatching success was independent of the order of laying.

The mean clutch size (Table 3) was highest at the Lighthouse in 1976 and lowest at Canada Furnace. The effect of clutch size on hatching success is in Table 6. For purposes of clarity data from the same colonies collected in 1973 and

TABLE 4

The influence of the order of laying on egg volume in 35, 3-egg clutches at the Lighthouse colony in 1976.

Egg	No. of Eggs	Mean volume (c.c) $\pm$ 1 S.E.
1	35	89.27 ± 1.39
2	35	90.05 ± 1.42
3	35	85.88 ± 1.32

TABLE 5

The influence of the order of laying on hatching success

	Canada Furnace '75			Lighthouse '75			Lighthouse '76		
Egg	#of eggs	#hatched	(%)	#of eggs	#hatched	(%)	#of eggs	#hatched	(%)
1	24	13	(54.2)	46	28	(60.9)	35	19	(54.3)
2	24	13	(54.2)	46	32	(69.8)	35	22	(62.9)
3	15[1]	10	(66.7)	42[1]	28	(66.7)	34[2]	22	(64.7)

[1] 9 and 4 3rd eggs collected from Canada Furnace and Lighthouse 1975.

[2] 1 egg broken - experimental error.

TABLE 6: Hatching Success related to clutch size in the Herring Gull colonies.

Colony	Clutch Size	1973[7] Eggs hatched (number clutches)	1973[7] Eggs hatched per egg laid	1974[7] Eggs hatched (number clutches)	1974[7] Eggs hatched per egg laid	1975 Eggs hatched (number clutches)	1975 Eggs hatched per egg laid	1976 Eggs hatched (number clutches)	1976 Eggs hatched per egg laid
Canada Furnace	1	1 (3)	0.333	0 (2)	0	0 (4)	0		
	2	4 (3)	0.667	4 (9)[1]	0.235	5 (8)	0.313		
	3	20 (14)	0.476	27 (25)[2]	0.450	44 (28)[2]	0.587		
	4	0 (1)	0	3(1)	0.750	- (0)	-		
	5	- (0)	-	- (0)	-	0 (2)	0		
	Total	25 (21)	0.455	34 (37)[3]	0.410	49 (42)[5]	0.467		
Lighthouse	1	0 (1)	0	2 (3)	0.667	- (0)	-	1 (3)	0.333
	2	21 (15)	0.700	23 (20)	0.575	8(7)	0.571	11 (9)	0.611
	3	46 (31)	0.495	52 (38)[2]	0.525	92 (48)[2]	0.657	77 (46)	0.570
	4	5 (2)	0.625	- (0)	-	2 (1)	0.500	- (0)	-
	5	- (0)	-	1 (1)	0.200	8 (4)	0.400	1 (2)	0.100
	Total	72 (49)	0.545	78 (62)[4]	0.531	110 (60)[6]	0.618	90 (60)	0.542

Notes:

1 1 egg broken by investigator

2 Including clutches from which on egg was collected.

3 4 nests destroyed artifically.

4 6 nests destroyed artifically

5 7 nests destroyed artifically

6 1 clutch collected

7 Morris and Haymes 1977

and 1974 (Morris and Haymes 1977) have been included. Hatching success was not consistently related to clutch size. Two-egg clutches realized a higher hatching success than three-egg clutches in four of the seven cases, although, the difference was marginally significant in only one instance (Lighthouse 1973; 2-egg clutches $>$ 3-egg cluthces; $X_c^2 = 3.07$; $0.1 > p > 0.05$).

Hatching success was a function of the time of clutch initiation (Table 7). Again, data collected in 1973 and 1974 have been included. The split dates for early versus late nesters was taken as the day after the peak when a substantial reduction in the number of new clutches occured. In six of the seven test cases early nesters realized a greater hatching success than late nesters (Table 7). At the Canada Furnace colony there were no significant differences in the hatching success of early versus late nesters in any year, although in 1974 the hatching success of late nesters was substantially below that of early nesters. At the Lighthouse colony eggs from early nests hatched significantly better than late nests in 1973 ($X_c^2 = 6.56$, $p < 0.02$), 1974 ($X_c^2 = 26.56$, $p < 0.001$) and 1975 ($X_c^2 = 6.28$, $p < 0.02$).

The data were reorganized to establish whether the higher hatching success of 2-egg or 3-egg clutches within a year was related to the distribution of the two clutch sizes in the early and late period of that year (Table 8). The data show that with one exception (Lighthouse 1973), hatching success was higher for the clutch size group with the greater early

TABLE 7

Hatching success related to time of clutch initiation in the Herring Gull colonies.

Colony	Time Period[1]	1973[2] Nests (n)	1973[2] Eggs Hatched per egg laid	1973[2] Mean Hatch per nest ($\pm$ 1 SE)	1974[2] Nests (n)	1974[2] Eggs Hatched per egg laid	1974[2] Mean Hatch per nest ($\pm$ 1 SE)	1975 Nests (n)	1975 Eggs Hatched per egg laid	1975 Mean Hatch per nest ($\pm$ 1 SE)	1976 Nests (n)	1976 Eggs Hatched per egg laid	1976 Mean Hatch per nest ($\pm$ 1 SE)
Canada Furnace	early	9	0.423	1.22$\pm$0.49	25	0.459	1.12$\pm$0.18	19	0.438	1.47$\pm$0.26	no data		
	late	12	0.483	1.17$\pm$0.34	12	0.273	0.50$\pm$0.29	23	0.412	0.91$\pm$0.22			
Lighthouse	early	25	0.657	1.84$\pm$0.19	49	0.649	1.51$\pm$0.12	33	0.680	2.06$\pm$0.16	38	0.568	1.66$\pm$0.15
	late	24	0.419	1.08$\pm$0.21	13	0.121	0.31$\pm$0.13	27	0.545	1.56$\pm$0.23	22	0.491	1.23$\pm$0.23

Note:

1 split date (see text): Canada Furnace, 1973 = May 2; 1974 = May 10; 1975 = April 30
Lighthouse, 1973 = May 1; 1974 = May 2; 1975 = April 28; 1976 = April 27

2 Morris and Haymes 1977

TABLE 8

Numbers of nest starts during early and late time periods for 2-egg and 3-egg clutches.

	Clutch Size	Canada Furnace early[1]	Canada Furnace late	Canada Furnace ratio of early/late	Lighthouse early	Lighthouse late	Lighthouse ratio of early/late
1973[3]	2-egg	2	1	2.0[2]	7	8	0.88[2]
	3-egg	6	8	0.75	16	15	1.07
1974[3]	2-egg	4	5	0.80	16	4	4.0[2]
	3-egg	20	5	4.0	29	9	3.2
1975	2-egg	0	8	0.0	2	5	0.4
	3-egg	18	10	1.8	27	21	1.28
1976	2-egg	no data			6	3	2.0[2]
	3-egg				30	16	1.88

Notes:

1 See Table 3 for split dates

2 years when the hatching success of 2-egg clutches exceeded that of 3-egg clutches.

3 Morris and Haymes 1977

to late ratio of nest starts.

The causes of egg failure are in Table 9. Embryonic mortality (ie. addled and failed to hatch) was the major cause of egg failure while disappearance and cracking were also important. The four major causes of egg failure according to clutch size and time of clutch initiation are in Table 10 and 11. There appeared to be no consistant trends although the following differences were significant. At the Lighthouse in 1975 disappearance was a more important cause of egg failure among late clutches than early clutches (X_c^2 = 11.72, $p < 0.001$) and failed to hatch was more important among early nesters (X_c^2 = 5.52, $p < 0.01$). In 1976 at the Lighthouse colony disappearance was more important among two-egg clutches than three-egg clutches (X_c^2 = 8.01, $p < 0.01$). All other comparisons at the Lighthouse and Canada Furnace colonies were not significant at the 5% level.

c. Fledging Success:

Fledging success in this section deals with non-manipulated control nests unless otherwise specified and includes base line data from 1974. Fledging success (% of chicks fledged; Table 12) ranged from 35.3% (Canada Furnace 1974) to 65.3% (Lighthouse 1976). In 1974 the fledging success was similar between the two colonies (35.3% - Canada Furnace, 38.5% - Lighthouse). Fledging success at the Lighthouse increased annually from 1974 through 1976. The difference between

TABLE 9

Causes of egg failure.

	Canada Furnace		Lighthouse			
		'75		'75		'76
Category	#	(rank)	#	(rank)	#	(rank)
Disappeared	14	(1.5)	14	(2)	9	(4.5)
Addled[1]	14	(1.5)	18	(1)	19	(2)
Failed to hatch[2]	13	(3)	13	(3)	12	(3)
Cracked	10	(4)	12	(4)	20	(1)
DWP[3]	4	(5)	6	(5)	9	(4.5)
Flooded	0		0		1	(8)
Rolled out	1	(6)	0		3	(7.5)

[1]Liquid feel when handled

[2]did not hatch when expected with no apparent reason

[3]Died while pipping

TABLE 10:

The influence of clutch size on the causes of egg failure.

Category	Canada Furnace '75 Clutch Size 2 n (% of failures)	Canada Furnace '75 Clutch Size 3 n (% of failures)	Lighthouse '75 Clutch Size 2 n (% of failures)	Lighthouse '75 Clutch Size 3 n (% of failures)	Lighthouse '76 Clutch Size 2 n (% of failures)	Lighthouse '76 Clutch Size 3 n (% of failures)
Cracked	3 (27.3)	6 (18.2)	3 (50.0)	9 (18.8)	1 (14.3)	18 (32.8)
Addled	3 (27.3)	8 (24.5)	0	13 (27.1)	2 (28.6)	14 (25.5)
Failed to hatch	3 (27.3)	5 (15.2)	0	10 (20.8)	0	11 (20.0
Disappeared	2 (18.2)	9 (27.3)	2 (33.3)	12 (25.0)	4 (57.1)	5 (9.1)
Total failures (% of total eggs)	11 (68.7)	33 (41.3)	6 (42.9)	48 (34.3)	7 (38.9)	55 (43.0)

TABLE 11:

The influence of the time of clutch initiation on the causes of egg failure.

Category	Canada Furnace '75 Early n (% of failures)	Canada Furnace '75 Late n (% of failures)	Lighthouse '75 Early n (% of failures)	Lighthouse '75 Late n (% of failures)	Lighthouse '76 Early n (% of failures)	Lighthouse '76 Late n (% of failures)
Cracked	3 (10.0)	7 (27.0)	4 (11.4)	8 (24.2)	9 (18.8)	11 (39.3)
Addled	9 (30.0)	5 (19.3)	11 (31.5)	7 (21.2)	16 (33.3)	3 (10.7)
Failed to hatch	6 (20.0)	7 (27.0)	11 (31.5)	2 (6.1)	8 (16.6)	4 (14.2)
Disappeared	8 (26.6)	6 (23.1)	1 (2.86)	13 (39.4)	5 (10.4)	5 (17.9
Total failures (% of total eggs)	30 (56.2)	26 (58.8)	35 (32.0)	33 (45.5)	48 (43.2)	28 (50.9)

TABLE 12

The influence of clutch size on fledging success at the Port Colborne colonies.

Colony	Clutch Size	1974 # of Nests	1974 # fledged (% of chicks)	1974 # fledged per egg laid	1975[6] # of Nests	1975[6] # fledged (% of chicks)	1975[6] # fledged per egg laid	1976[6] # of Nests	1976[6] # fledged (% of chicks)	1976[6] #fledged per egg laid
Canada Furnace	1	2	0 (-)	0.0						
	2	9[1]	0 (0.0)	0.0						
	3	25[2]	12 (44.4)	0.20						
	4	1	0 (0.0)	0.0						
	5	0	-	-						
	Total	37[3]	12 (35.3)	0.14						
Lighthouse	1	3	0 (0.0)	0.0	0	-	-	3	1 (100.0)	0.33
	2	20	13 (56.5)	0.33	5	3 (75.0)	0.30	6	3 (60.0)	0.25
	3	38[2]	16 (30.8)	0.16	28	17 (41.5)	0.21	31	27 (64.3)	0.30
	4	0	-	-	1	0 (0.0)	0.0	0	-	-
	5	1	1 (100.0)	0.20	4	5 (62.5)	0.25	2	1 (100.0)	0.10
	Total	62[4]	30 (38.5)	0.21	38[5]	25 (45.5)	0.22	42[5]	32 (65.3)	0.28

[1] 1 egg broken by investigator
[2] including clutches from which 1 egg was collected
[3] 4 nests destroyed artifically
[4] 6 nests destroyed artifically
[5] 1 clutch collected
[6] control nests only

1974 and 1976 was significant ($X_c^2 = 7.64$, $p < 0.01$) and between 1975 and 1976 was marginally so ($X_c^2 = 3.36$, $0.1 > p > 0.05$). There were no significant differences in the number fledged per egg laid.

Fledging was correlated to egg volume in 1976 (Table 13). The proportion of chicks which fledged appeared to increase with egg volume for non-manipulated nests and consistently increased with egg volume when all nests (experimental and control) were considered. The fledging success (on a per-egg hatched basis) was significantly higher for eggs over 95.0cc than those below 85cc ($p = 0.03$; Fisher Exact Probability Test; Siegel 1956).

Similar to hatching success, fledging success did not appear to be related to clutch size (Table 12) although the difference between 2-egg (75.0%) and 3-egg (41.5%) clutches at the Lighthouse in 1975 approached significance, ($X_c^2 = 3.44$, $0.1 > p > 0.05$).

The influence of the time of clutch initiation on fledging success revealed that early nesters experienced a higher percent fledged and a larger number of chicks fledged per egg laid than late nesters (Table 14). The difference in the number of chicks fledged per egg laid was significant in 1974 at both Canada Furnace ($X_c^2 = 5.44$, $p < 0.02$) and the Lighthouse ($X_c^2 = 4.48$, $p < 0.05$).

TABLE 13

The influence of egg volume on fledging success at the Lighthouse colony in 1976.

	Egg volume	#of eggs	#of eggs hatched	# fledged (% of hatched)	# fledged per egg laid
Controls[1]	< 80	13	3	1 (33.3)	0.08
	80-84.99	24	9	6 (66.7)	0.25
	85-89.99	22	13	8 (61.5)	0.36
	90-94.99	20	9	6 (66.7)	0.30
	95-99.99	7	1	1 (100.0)	0.14
	> 100	10	5	5 (100.0)	0.50
All	< 80	19	8	3 (37.5)	0.16
	80-84.99	35	18	11 (61.1)	0.31
	85-89.99	37	26	16 (61.5)	0.43
	90-94.99	28	16	12 (75.0)	0.43
	95-99.99	12	5	4 (80.0)	0.33
	> 100	11	6	6 (100.0)	0.55

[1]brood size not manipulated

TABLE 14

The influence of the time of clutch initiation on fledging success at the Port Colborne colonies.

Colony	Year	Period	No. of nests	No. Fledged (%of chicks)	No. fledged per egg laid	No. fledged per nest
Canada Furnace:	1974[2]	Early	25	11 (39.3)	0.18	0.44
		Late	12	1 (16.7)	0.05	0.08
Lighthouse:	1974[2]	Early	49	28 (37.8)	0.25	0.57
		Late	13	2 (50.0)	0.06	0.15
	1975[1]	Early	15	12 (48.0)	0.23	0.80
		Late	23	13 (43.3)	0.21	0.57
	1976[1]	Early	24	22 (68.8)	0.30	0.92
			18	10 (58.8)	0.23	0.56

1 control nests only

2 Morris and Haymes 1977

Although carcasses were found for many lost chicks over the three years, a large proportion of chicks disappeared without a trace before fledging (58.3%, 25.8% and 23.5% of the total losses in 1974, 1975 and 1976 respectively at the Lighthouse and 22.7% at Canada Furnace in 1974). Most chick losses occured during the first two weeks post-hatch, however, losses from day 15 to day 30 were substantial (Figure 9).

d. <u>Toxic Chemicals</u>:

Residue levels of four organochlorine substances identified in Herring Gull eggs from the Port Colborne colonies in 1974 and 1975 are given in Table 15. In each year, PCB's were present at considerably higher levels than any of the DDT fractions. The range limits of all four components were greater in 1974 than in 1975 and the mean values for each were lower in 1975. A Mann-Whitney U-test analysis (Siegel 1956) revealed that PCB contamination was significantly lower in the 1975 sample than in the 1974 sample ($U = 19$, $p < 0.01$). The three DDT fractions for each year were combined and treated as a single contaminant. The test revealed no difference between the 1974 and 1975 samples ($U = 44$, $p > 0.1$).

e. <u>Incubation Attention</u>:

The majority of nests monitored ($n = 19$) were incubated more than 95% of the time (57-60 min/hr). Incubation appeared to be independent of clutch size and time of clutch initiation (Table 16) and birds which incubated less than 75% of the time

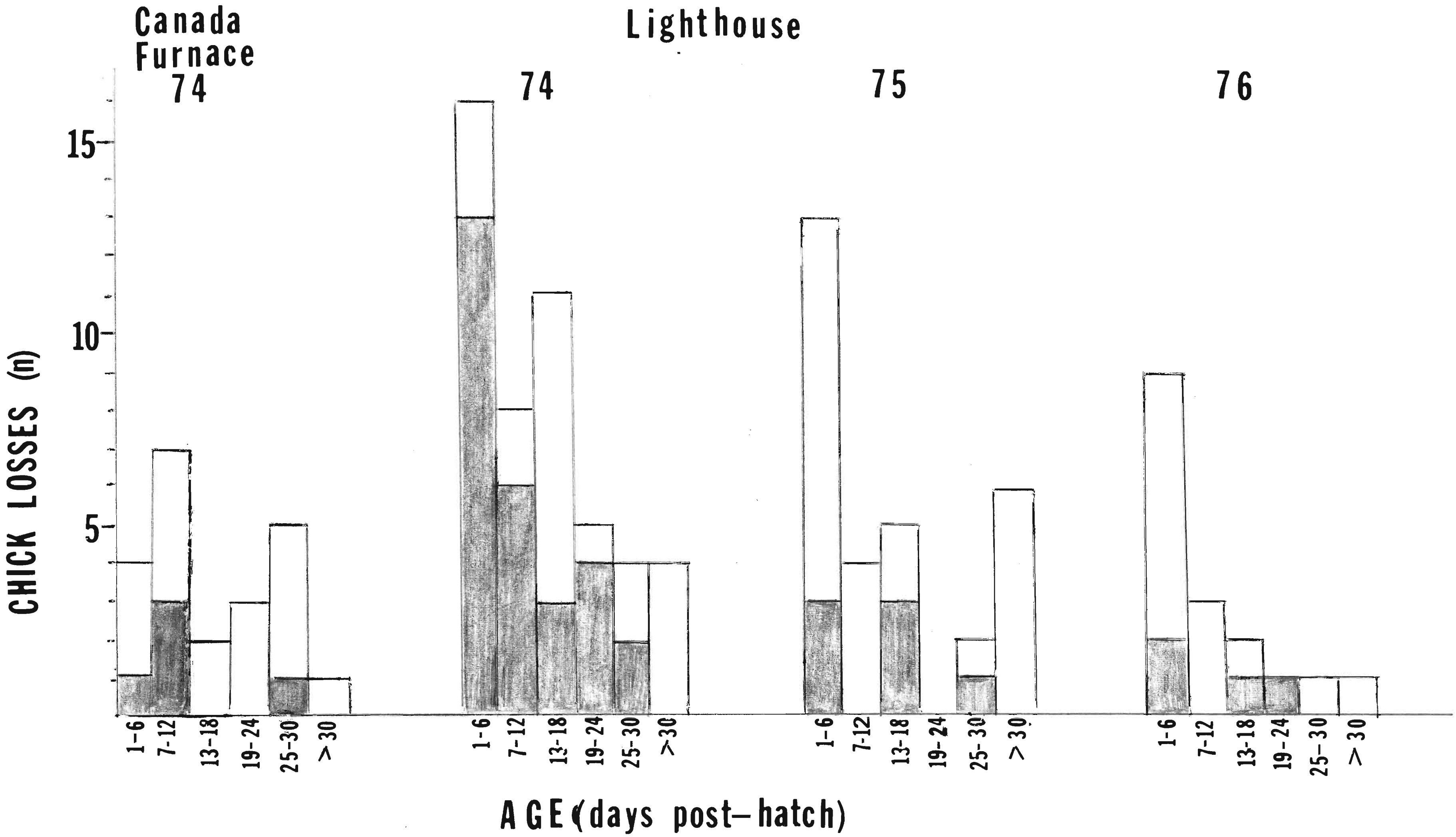

Figure 9: Chick losses according to age at the Port Colborne colonies. Solid areas refer to those which disappeared.

TABLE 15

Residue content[1] of Herring Gull eggs collected from the Port Colborne Lighthouse colony in late May, 1974 and 1975.

Substance	1974 (n=10) arith. mean	1974 (n=10) (range)	1974 (n=10) geom. mean	1975 (n=12) arith. mean	1975 (n=12) (range)	1975 (n=12) geom. mean
DDE	8.71	(4.88-14.3)	8.15	7.63	(6.15-12.0)	7.46
DDD	0.130	(0.08-0.21)	0.129	0.069	(0.05-0.09)	0.068
pp'DDT	0.061	(0.04-0.10)	0.058	0.028	(0.01-0.06)	0.025
PCB[2]	72.56	(42.6-110.0)	70.27	52.65	(41.2-87.4)	51.53

Notes:

1 in parts per million, wet weight

2 based on 1:1 mixture of Aroclor 1260:1254

TABLE 16:

The effect of clutch size and time of clutch initiation on incubation attention[2].

	3-egg clutches		Early Clutches	
Time on nest (min/hr.)	Early # of nest (%)	Late # of nests (%)	2-egg # of nests (%)	3-egg # of nests (%)
57-60	13 (68.4)	3 (60.0)	3 (75.0)	13 (68.4)
54-56.9	0	0	0	0
51-53.9	0	1 (20.0)	0	0
48-50.9	1 (5.3)	0	1 (25.0)	1 (5.3)
45-47.9	1 (5.3)	0	0	1 (5.3)
-44.9	4 (21.1)	1 (20.0)	0	4 (21.1)
Total	19	5	4	19

1 a sample of 28 nests monitored during day 14-27 post-lay for 41-169 hours, mean 113.7± 7.8 (S.E)

(45.0 min/hr) were as successful in hatching eggs as birds incubating 95% of the time (Table 17). The differences in the distribution of nests incubated 95% of the time and those less than 95% of the time between early and late nests and 2 and 3-egg clutches were not significant ($p = 0.4$ and $p = 0.5$ respectively; Fisher Tests). Also, the difference in hatching success between those 3-egg clutches incubated more than 95% of the time (60.4%, $n = 16$ nests) and incubated less than 95% of the time (66.7%, $n = 8$) was not significant ($X_c^2 = 0.07$, $p > 0.1$).

The incubation data were separated into three eight hour time periods; morning (0500 - 1300 hrs), afternoon (1300 - 2100 hrs) and night (2100 - 0500 hrs). Although the mean incubation time of 3-egg clutches ($n = 24$) during these periods range from 37.31 to 59.08, 22.47 to 59.21, 19.19 to 59.75 minutes per hour, respectively, the night period (2100 - 0500 hrs) was highest in 19 of 24 cases. No significant day to day differences (Mann-Whitney U-test) in incubation time were found among the night periods (Table 18); however differences were found in incubation attention between days during the two diurnal periods. Table 19 lists these comparisons, where data were available, however, no apparent trend was discernable.

TABLE 17

The effect of incubation attention on egg loss and hatching success in 3-egg clutches[1].

	# of eggs lost from 3-egg clutches				
Time on nest (min/hr.)	0 n (%)	1 n (%)	2 n (%)	3 n (%)	Hatching success (%)
57-60	3(50.0)	8(72.7)	4(80.0)	1(50.0)	60.4
54-56.9	0	0	0	0	-
51-53.9	0	0	0	1(50.0)	0.0
48-50.9	0	1(9.1)	0	0	66.7
45-47.9	1(16.7)	0	0	0	100.0
$<$ 44.9	2(33.3)	2(18.2)	1(20.0)	0	73.3
Total	6	11	5	2	

1 a sample of 28 nests monitored during day 14-27 post-lay for 41-169 hrs, mean 113.7 ± 7.8 (S.E.).

TABLE 18

Mean time spent on nest in minutes ($\pm$ 1SE, n=11) during three time periods on the dates indicated.

TIME PERIOD:	DATE (MAY, 1976)							
	16	17	18	19	20	21	22	23
MORNING:			437$\pm$19	403$\pm$28	439$\pm$15	450$\pm$22	464$\pm$3	459$\pm$6
AFTERNOON:	411$\pm$37	432$\pm$21	422$\pm$43	432$\pm$24	446$\pm$19	423$\pm$15	409$\pm$25	
NIGHT:		452$\pm$24	469$\pm$5	443$\pm$18	467$\pm$6	468$\pm$8	462$\pm$11	458$\pm$14

TABLE 19

Mann-Whitney U-test results of differences in Table 18 for morning and afternoon samples. None of the differences in the night sample was significant.

	Date (May 1976)	Morning 16 U	16 p[1]	17 U	17 p	18 U	18 p	19 U	19 p	20 U	20 p	21 U	21 p	22 U	22 p	23 U	23 p
AFTERNOON	17	45	NS[2]			–		–		–		–		–		–	
	18	29	.025	28	.025			20.5	.01	40	NS	27	.025	47.5	NS	52	NS
	19	30	.025	36	NS	35	NS			26.5	.025	14	.001	8	.001	22	.01
	20	29	.025	31.5	.05	39.5	NS	58	NS			22	.01	25.5	.025	38	NS
	21	36	NS	38	NS	27	.025	31	.05	29	.025			31	.05	34.5	NS
	22	37	NS	35.5	NS	26	.025	30	.025	26	.025	54	NS			59	NS

[1] $p <$

[2] not significant

f. Brood Manipulations and Chick Growth:

In 1975 transplanted chicks (n = 22) realized a fledging success (59.1%) similar to their non-transplanted brood mates (n = 27,55.6%). However in 1976 transplanted chicks (n = 22) realized a significantly higher fledging success (81.8%, $X^2_c = 4.28$ $p < 0.05$) than non-transplanted brood mates (n = 23, 47.8%) This difference in 1976 did not appear to be a result of biased sampling. Egg volumes, where known, were similar between transplanted and non-transplanted chicks (86.64 $\pm$ 2.78 cc, n = 9 and 86.19 $\pm$ 1.29, n = 23 respectively). On the average transplanted chicks tended to be younger (1.9 $\pm$ 0.4 days, n = 10) and lighter (76.05 $\pm$ 2.23g. n = 22) than their non-transplanted brood mates (2.2 $\pm$ 0.3 days, n = 23 and 81.22 $\pm$ 2.78 g, n = 23).

Fledging success (% chicks fledged) of all control and experimental broods varied from 40.7% to 83.3% in 1975 and from 55.0% to 87.5% in 1976 (Table 20). Fledging success was highest in 1-chick experimental broods reduced from 2 and 3 chicks in both years. A marginally significant difference in fledging success (p = 0.07, Fisher exact probability test) was shown in only one of all possible test comparisons (3-chick controls $<$ 2-chick broods reduced to 1-chick in 1975). Although differences (non-significant) existed between brood size groups in fledging success (excluding 1-chick expermientals) in both years, the pooled data show that fledging success did not vary between brood sizes. As a consequence, the number of young fledged

TABLE 20:

The influence of brood size on fledging success and fledging weight at the lighthouse in 1975 and 1976

Brood Size	#of chicks	Fledging success #fledged (%)	#fledged per brood ±1SE.	Mean weight at fledging ±1SE
1975				
1*	10	5 (50.0)	0.50±0.17	898±25
2 - 1**	6	5 (83.3)	0.83±0.17	843±102
3 - 1***	5	4 (80.0)	0.80±0.20	928±91
2*	18	9 (50.0)	1.00±0.24	874±39
3*	27	11 (40.7)	1.22±0.36	886±26
4	24	15 (62.5)	2.50±0.43	903±33
5	25	13 (52.0)	2.60±0.40	878±24
1976				
1*	13	8 (61.5)	0.62±0.14	868±46
2/3 - 1	8	7 (87.5)	0.88±0.13	1007±50
2*	24	15 (62.5)	1.25±0.22	886±33
3*	12	9 (75.0)	2.25±0.25	908±27
4	20	11 (55.0)	2.20±0.20	818±46
5	25	18 (72.0)	3.60±0.60	850±28
Pooled				
1*	23	13 (56.5)	0.57±0.11	
2/3 - 1	19	16 (84.2)	0.84±0.09	
2*	42	24 (57.1)	1.14±0.16	
3*	39	20 (51.3)	1.54±0.29	
4	44	26 (59.1)	2.36±0.24	
5	50	31 (62.0)	3.10±0.38	

* Controls.

** Two-chick broods reduced to one-chick.

*** Three-chick broods reduced to one chick.

per pair of adults increased with brood size (Table 20).

Despite high variation in weight at fledging, the mean fledging weight (at 30 days post-hatch) of chicks from each control and experimental brood groups showed remarkable consistency(Table 20). Curves of log transformed weight data standardized by division by the mean hatching weight of the brood size group from which the data came, revealed two straight portions. An exponential increase occurred from day 4 to day 10 post-hatch and an exponential decrease to asymptote occurred from day 18 to 27. Linear regression analysis of the growth data from these two intervals revealed significant correlation coefficients ($p<0.01$) for all brood sizes except one (Table 21). During the early growth period (day 4-10) in 1975, the slopes of the regression lines decreased as brood size increased with the single exception of one chick control broods (Table 21). There were no consistent trends in the slopes of the regression lines from the late period of 1975 nor the early and late periods of 1976.

The following significant differences occurred between regression line slopes; in 1975 the growth rate of 2-chick broods reduced to one chick exceeded that of 5-chick broods during the early growth period ($F=28.04$, $p<0.01$; Snedecor and Cochran 1967); in 1976 the growth rate during the early phase of 2-chick control broods was less than 3-chick control broods ($F = 5.94$, $p<0.05$), 2 and 3-chick reduced to one chick ($F = 6.44$, $p<0.05$) and 5-chick experimental broods ($F = 4.83$, $p<0.05$). None of the comparisons during the late period was significant.

TABLE 21

Linear regression[1] of chick weights from each brood size group during early (day 4-10) and late (day 18-27) growth phases in 1975 and 1976[2].

		1975					1976				
	Brood size	# of chicks	A	B±1SD.	Corr. Coeff.	p<	# of chicks	A	B ±1SD	Corr Coeff.	p<
	1	5	-0.122	.068±.003	.958	.01	8	-.011	.064±.003	.944	.01
	2-1	5	-.160	.078±.004	.958	.01	7	-.149	.075±.003	.956	.01
	3-1	4	-.088	.078±.007	.906	.01					
Early	2	6	-.153	.076±.004	.947	.01	10	-.051	.058±.003	.891	.01
	3	6	-.153	.070±.006	.881	.01	3	-.283	.083±.007	.938	.01
	4	4	-.061	.068±.005	.937	.01	4	-.061	.066±.003	.978	.01
	5	5[3]	-.121	.064±.006	.878	.01	10	-.126	.071±.002	.958	.01
	1	5	.532	.019±.001	.793	.01	8	.668	.016±.001	.665	.01
	2-1	5	.647	.014±.003	.494	.1 > p > .05	7	.678	.017±.001	.777	.01
	3-1	4	.670	.016±.002	.692	.01					
Late	2	6	.604	.017±.001	.870	.01	10	.572	.019±.001	.804	.01
	3	6	.521	.022±.001	.870	.01	3	.640	.016±.001	.803	.01
	4	4[3]	.540	.020±.001	.923	.01	4	.526	.022±.001	.903	.01
	5	5	.597	.016±.001	.865	.01	10	.584	.018±.001	.808	.01

1 $Y = A + Bx$

2 only broods from which all chicks fledged

3 contains one chick which died after day 30 but maintained normal growth up to day 30.

6. DISCUSSION

A. Hatching Success:

Hatching success of Herring Gull eggs from colonies outside the Great Lakes were reported by Paynter (1949) on Kent Island, New Brunswick (71.0%, n = 100 nests); by Harris (1964) on Skomer, Wales (64.1%, n = 220-360 nests); by Brown (1967) on Walney Island, England (66.6%, n = 350 eggs), by Haycock and Threlfall (1975) on Newfoundland (62.5% and 72.9%, n = 88 eggs and 273 eggs) and by Parsons (1975) on the Isle of May (64.3% n = 1101 nests - 69.9%, n = 903 nests). In this study the hatching success of eggs at both colonies in each year (Table 6) was lower than any of these values but considerably higher than hatching rates reported by Gilbertson and Hale (1974b) for a colony on Scotch Bonnet Island in Lake Ontario (16%, n = 97 nests). Elsewhere in the Great Lakes hatching success in 1975 varied from a high of 79.6% (n = 101 nests) on Granite Island, Lake Superior to a low of 18.6% (n = 53 nests) on Scotch Bannet, Lake Ontario (Gilman *et al ms*). Thus, the Port Colborne colonies in 1975 realized a hatching rate intermediate in the success range reported throughout the Great Lakes.

The data show (Figure 7) that at the Lighthouse colony the early time period was the most tightly synchronized set of nest starts, however, at the Canada Furnace colony the early peak was much reduced and nest starts were more scattered over the breeding season. This may have been due to the low density of nests reducing the proposed synchronization advantage gained through social stimulation (cf. Darling 1938). Parsons (1975) suggested that eggs laid at the time when most laying occurred were most likely to hatch regardless of the time of peak laying. Thus, late breeding would not necessarily be disadvantageous providing the delay applied to the group as a whole. Hence the high hatching success of early nesters (Table 7) would appear to be a function of synchronization rather than season.

The hatching success of eggs at both the Lighthouse and Canada Furnace colonies appeared to be independent of clutch size. Parsons (1975) showed that three-egg clutch parents relaying smaller clutches following the removal of their original clutches realized a higher hatching success than that of small first clutches but lower than three-egg second clutches. He suggested, therefore, that irrespective of the time of clutch initiation, a bird laying fewer than three eggs consistently hatched a smaller percentage of eggs. My data (Table 6) do not support this suggestion.

Chabrzyk and Coulson (1976) showed that young and/or inexperienced birds lay smaller clutches and later in the season than older experienced birds. It has also been suggested that small clutches do not present adequate incubation stimuli to the parents (Beer 1961, Brown 1967) and that small clutches represent low reproductive or incubative drive of the adults laying them (Parsons 1975). However, the incubation results (Table 16) do not conform with either of these suggestions as two-egg clutches were incubated at the same rate as three-egg clutches. Similarly, since no differences in incubation attention were revealed between early and late nesters, the data do not conform with the suggestion that birds laying late in the season are poor parents at least with respect to incubation attention.

I interpret the influence of the interaction between clutch size and time of clutch initiation as follows. In years when, at either colony, the proportion of two-egg clutches produced in the early period exceeded that of three-egg clutches produced during the same time period (Table 8), the hatching success of two-egg clutches exceeded that of three egg clutches (Table 6). The hatching success of the two clutch size groups was reversed when a greater proportion of three-egg clutches was produced early. This suggests that time of clutch initiation is of perhaps greater importance to hatching success than clutch size by itself at the Port Colborne colonies.

Embryonic mortality (failed to hatch and addled) was the major cause of egg loss in each year (Table 9). These levels are similar to levels of embryonic mortality reported by Keith

(1966) in Green Bay Wisconsin and below levels reported for Scotch Bannet Island in Lake Ontario (Gilbertson 1974, Gilman *et al ms*).

Disappearance and cracking were also important causes of egg loss in 1975 and 1976. Disappearance of eggs is a common problem in studies of colonial seabirds and the loss is usually attributed to predation. Brown (1967) suggested that cannibalism by neighbouring Herring Gulls was responsible for a large disappearance of eggs from his colony. Despite intensive diurnal and nocturnal observations not a single case of cannibalism or predation by other birds or mammals was witnessed although several potential predators were observed adjacent to the colonies. These included a Black-crowned Night Heron (*Nycticorax nycticorax*); a Great Horned Owl (*Bubo virginianus*, not a positive identification); a muskrat, (*Ondatra zebethica*) at the Lighthouse colony and a Red Fox, (*Vulpes fulva*) at the Canada Furnace colony.

Although differences occured within categories of egg failure between 2-egg and 3-egg clutches (Table 10) and between early and late nesters (Table 11) there appeared to be no consistent trends and the cause of these difference is unknown.

Hatching success was independent of incubation attention (Table 17). Although there must be some lower limit of incubation rate below which eggs will not hatch, gull eggs are extremely tolerant to cooling (Hunter *et al* 1976). Besides maintaining a suitable temperature and humidity for the eggs, incubation also provides protection from predation. However, since the predation pressure at the Lighthouse colony is apparently low, a low incubation rate appeared to have little influence on the success of the eggs being incubated.

Differences in incubation attention rates between the night period (2100 - 0500) and the diurnal periods (Table 18, 19) may be a function of human interference, including that of the investigator. Daily differences in incubation attention during diurnal periods may have been related to human interference and a number of weather parameters, including temperature, precipitation and hours of sunshine, although no general trend was evident, (Port Colborne weather records).

Egg volume in Herring Gulls has been shown to increase with age (Davis 1975, Chabrzyk and Coulson 1976) and the age of the breeding adults has been shown to be directly related to reproductive success (Chabrzyk and Coulson 1976). My data show that the mid size eggs which were the most common were also the most successful (Figure 8) although extremely large eggs were more successful than extremely small eggs. Fledging success (on a per egg hatched basis) was directly related to egg volume (Table 13). These results are similar to those of Parsons (1970).

b. Fledging Success:

The fledging success rates of the Lighthouse colony in 1975 was intermediate between those of Lake Ontario and Lake Huron and Superior (Gilman *et al ms*) and were generally lower than values for colonies outside the Great Lakes. On the basis of chicks fledged per nest, Paynter (1949) found 0.03 - 1.0 on Kent Island N.B.; Harris (1964) 0.6 on Skomer, Wales; Parsons (1975) 0.67 - 0.91 on the Isle of May, and Haycock and Threlfall (1975) slightly less than 1.0 on Newfoundland.

Considerable caution must be employed when comparative statements of fledging (and hatching) are made as these measures are dependent upon several parameters related to the intensity of the study. These include the frequency of visits, the date when the study was begun, whether nests were fenced or not, and the age at which chicks were considered fledged. When visits are limited to every six days (Keith 1966) or once weekly "weather permitting" (Gilbertson 1974) results must be interpreted with care. Herring Gulls normally begin laying in late April over most of their breeding range, however the study of Paynter (1949) was initiated on June 12 and Harris (1964) in mid May. Fencing nests can help fascilitate easy capture of chicks for identification and reduce territorial breakdown and chick mortality by neighbouring gulls caused by the investigators presence. There is little agreement in the literature on the actual age at fledging of Herring Gull chicks. Dates used include those of Haycock and Threlfall (1975; age at first strong flight, 42-48 days), Paynter (1949, mean of 43 days), Kadlec et al (1969, mean of 51 days), Gilman et al (ms, arbitrarily set at 21 days), Parsons (1975 10 days), Brown (1969, 10 days), Keith (1966, 40 days) and Haymes (this study, 30 days).

Fledging success (on a per egg hatched basis) was generally independent of brood size but the number of chicks fledged per brood increased with an increase in brood size (Table 20). Thus, Herring Gulls at this colony appeared able to adjust their foraging habits to accommodate additional chicks. Removal of chicks from two and three-chick broods enhanced the fledging potential of the remaining chick compared to two and three-chick control broods. Furthermore, parents which lost one or more eggs before hatching (1-chick controls) were unable to raise the single chick better than parents with larger broods.

In 1975 in broods of more than one chick, the rate of growth during the early growth phase decreased with brood size (Table 21) although no such trend was seen in 1976. However, the differences were small and chick weight at fledging was similar among brood sizes (Table 20). These data demonstrate that chicks from the larger experimental broods survived the pre-fledge period as well as those from smaller control broods and were at no weight (or viability) disadvantage despite the presence of a larger number of brood mates. No quantitative data were collected on food availability or on the rate of feeding visits by parents of the different brood sizes. However, the data strongly suggest that food was not limiting either the growth rate or fledging success of chicks from broods larger than the modal clutch size (3) of this species.

c. Toxic Chemicals:

While data from some of the colonies are not directly comparable, it is clear that colonies on Lake Erie were considerably more successful than those on Lake Ontario. Gilbertson (1974) attributed the poor reproductive success of his Lake Ontario colonies to a high toxic chemical residue load in the eggs and in the adult birds. The residue levels of the Port Colborne eggs (Table 15) were lower than residue levels in eggs from two colonies in Lake Ontario (Muggs Island and West Brothers) taken during the same years. The total DDT (DDE, DDD, pp'DDT) level was 22.81 $\pm$ 1.77 ppm (1974, n = 19) at Muggs Island and 22.88 $\pm$ 1.28 ppm (1975, n = 20) at West Brothers. The PCB levels in the same eggs was 152 $\pm$ 11.16 ppm and 143.11 $\pm$ 11.92 ppm respectively (Morris and Haymes 1977)

Although cause and effect relationships have not yet been established, the data collected to date indicate that Lake Ontario Herring Gulls are reproducing at a lower success rate than Lake Erie Herring Gulls (at least at the colonies studied) and suggest that toxic chemicals may be contributing to the difference. While the reproductive success of the Lake Erie colonies appear sufficient to maintain numbers there, the reproductive success of several Lake Ontario colonies (Gilbertson and Hale 1974 a, b; Gilman et al ms) reveal the potential for an imminent and continuing decline in those breeding populations.

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